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Title: Evolution of Internal Dosimetry: ICRP Metabolic and Dosimetric Models

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# *Evolution of Internal Dosimetry: ICRP Metabolic and Dosimetric Models*

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**Los Alamos National Laboratory**
**Los Alamos, NM - USA**

**Inaugural Lecture at the Postgraduate Program of the**
**Institute of Radiation Protection and Dosimetry**
**Rio de Janeiro, RJ – Brazil**
**March 1, 2021**

# *Internal Dosimetry: An Intersection of Disciplines*

- **Physiology,**
- **Anatomy,**
- **Physics,**
- **Mathematics,**
- **Computer Science,**

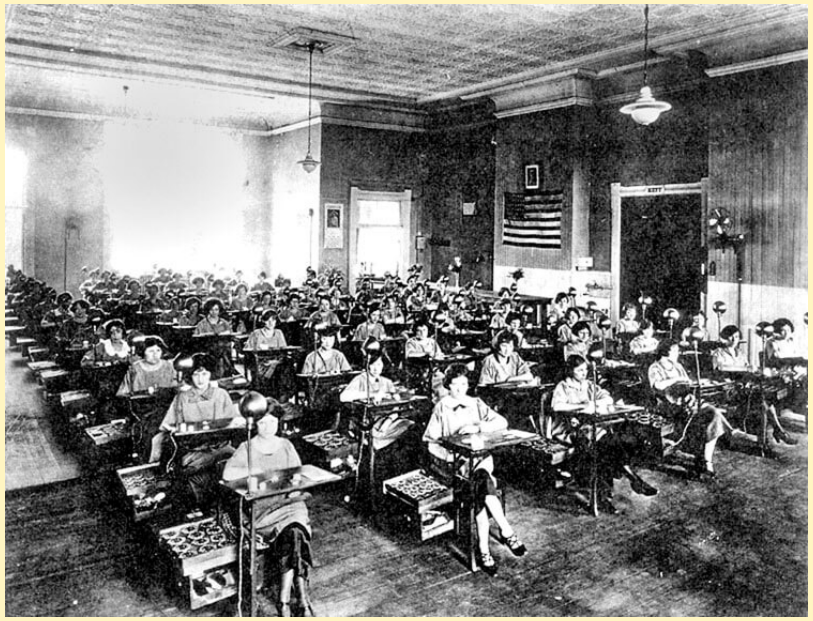
- **Some people call it**
- **“The art of Internal Dosimetry”!**

# *Basic Components for Internal Dose Calculations*

- **Metabolic models describing the intake, distribution, retention and excretion of radionuclides in the body.**
- **Dosimetric models describing the interaction of radiation within the several body organs and tissues.**
- **System of Dose Limitation**

# *Radium Girls*

**ICRP Publication 2, 1959:**
**"The effective RBE dose delivered to the bone from internal or external radiation during any 13 week period averaged over the entire skeleton shall not exceed the average RBE dose to the skeleton due to a body burden of 0.1 μCi of $^{226}Ra$. This is considered to correspond to a dose rate of 0.56 rem/week in the case of $^{226}Ra$."**




**Netflix**

# *Reference Man*

**A person with the anatomical and physiological characteristics defined in the report of the ICRP Task Group on Reference Man (ICRP-23, 1975 and ICRP-89, 2003).**

# *Tissues with assigned risk factors by ICRP: Publications 26 (1977), 60 (1990) and 103 (2007)*

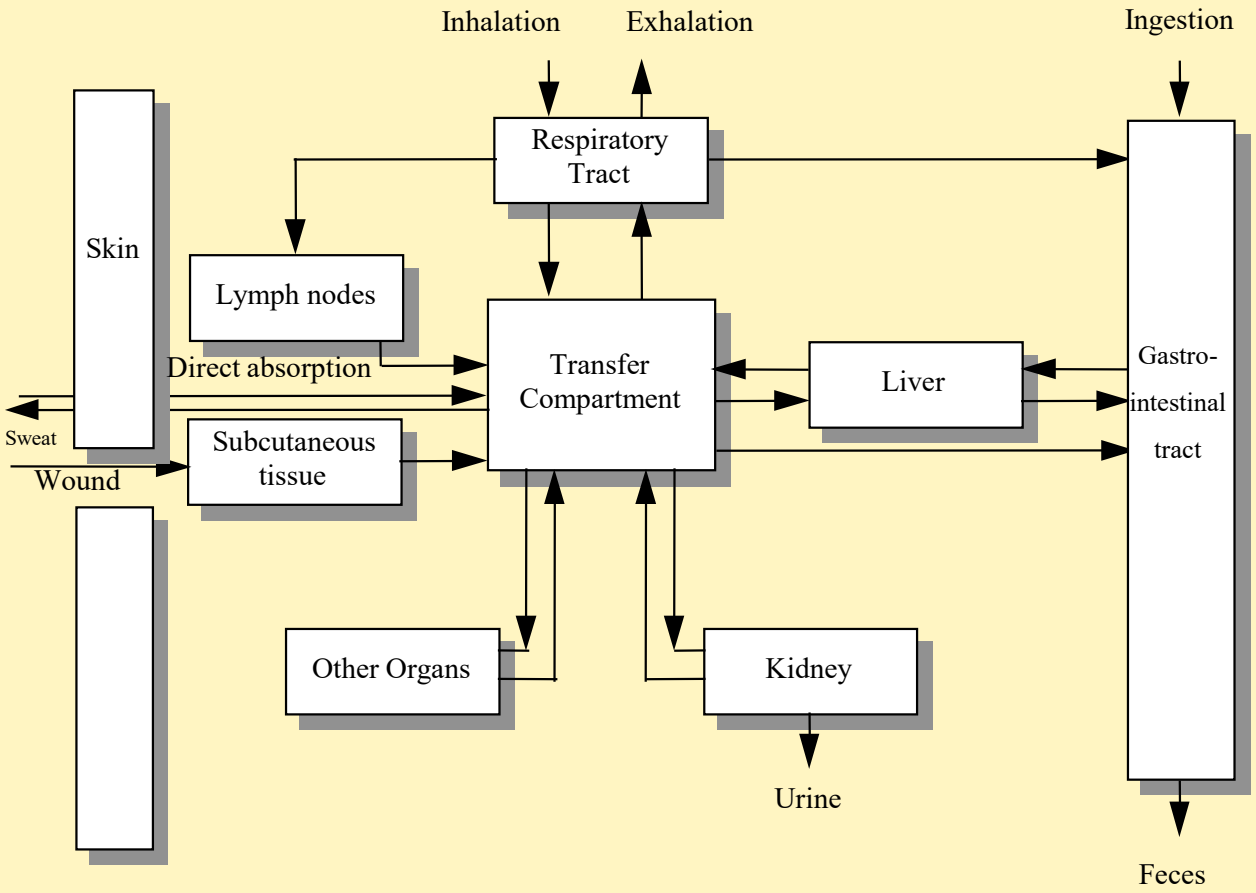
| Organ or Tissue | ICRP-26 | ICRP-60 | ICRP-103 |
|---|---|---|---|
| Gonads | X | X | X |
| Breast | X | X | X |
| Red Marrow | X | X | X |
| Lungs | X | X | X |
| Bone Surface | X | X | X |
| Thyroid | X | X | X |
| Bladder | ---- | X | X |
| Colon | ---- | X | X |
| Liver | ---- | X | X |
| Esophagus | ---- | X | X |
| Skin | ---- | X | X |
| Stomach | ---- | X | X |
| Brain | ---- | ---- | X |
| Salivary Glands | ---- | ---- | X |
| Remainder (*) | X | X | X |

**ICRP-26 Remainder tissues (Choice of 5):** Adrenals, Bladder, Brain, Stomach, Small Intestine, Upper Large Int., Lower Large Int., Kidneys, Liver, Muscle, Pancreas, Skin, Spleen, Thymus, Uterus.

**ICRP-60 Remainder tissues (All 10):** Adrenals, Brain, Extrathoracic (ET) region, Kidneys, Muscle, Pancreas, Small intestine, Spleen, Thymus, Uterus.

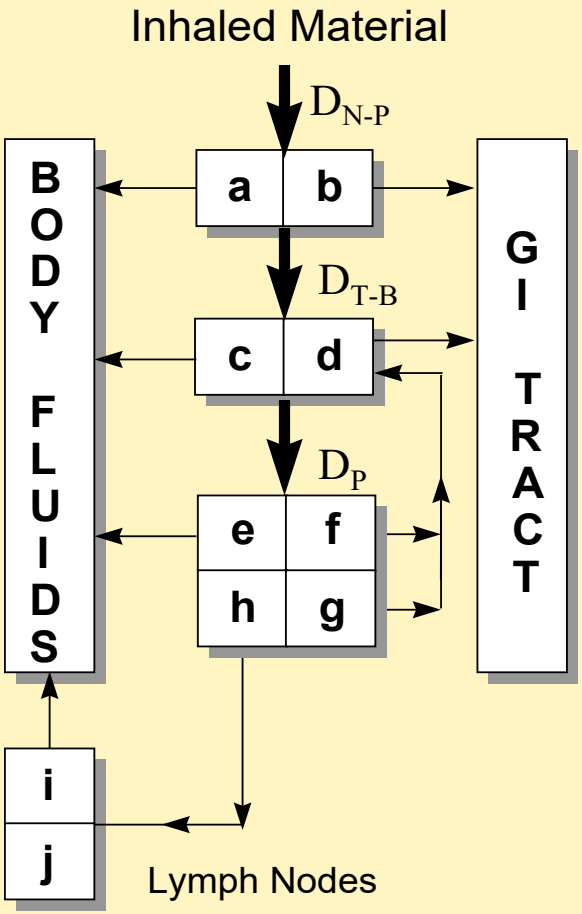
**ICRP-103 Remainder tissues (All 13):** Adrenals, Extrathoracic (ET) region, Gall Bladder, Heart, Kidneys, Lymphatic nodes, Muscle, Oral mucosa, Pancreas, Prostate (♂), Small intestine, Spleen, Thymus, Uterus/cervix (♀).

# A General Biokinetic Model Showing Routes of Intake, Transfers and Excretion



# *Evolution of the Respiratory Tract Models*

# The ICRP Publication 30 Respiratory Tract Model (1979)

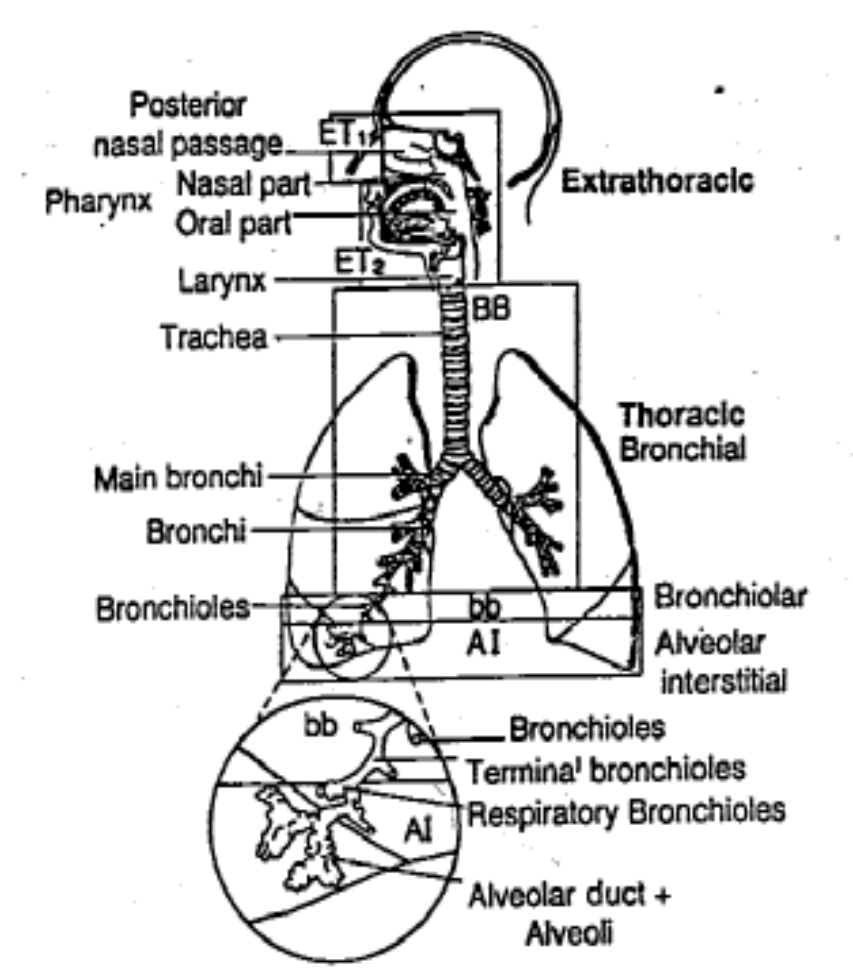



**Deposition of particles:**
**Default: AMAD = 1 μm**

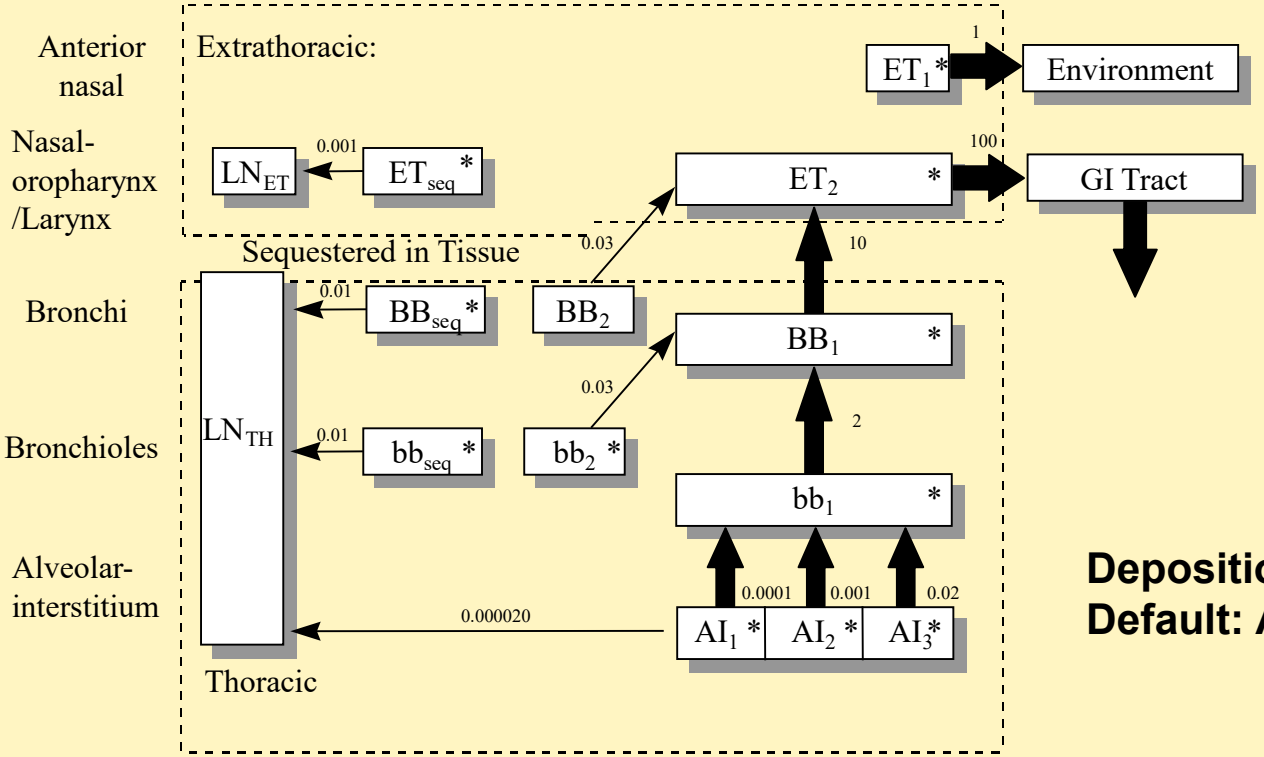
**Clearance: retention of compounds in pulmonary region.**

- **Class D: half-times < 10 days**
- **Class W: 10 < half-times < 100 days**
- **Class Y: half-times > 100 days**

# *Respiratory Tract Regions Defined in the ICRP Publication 66 Model (1994)*

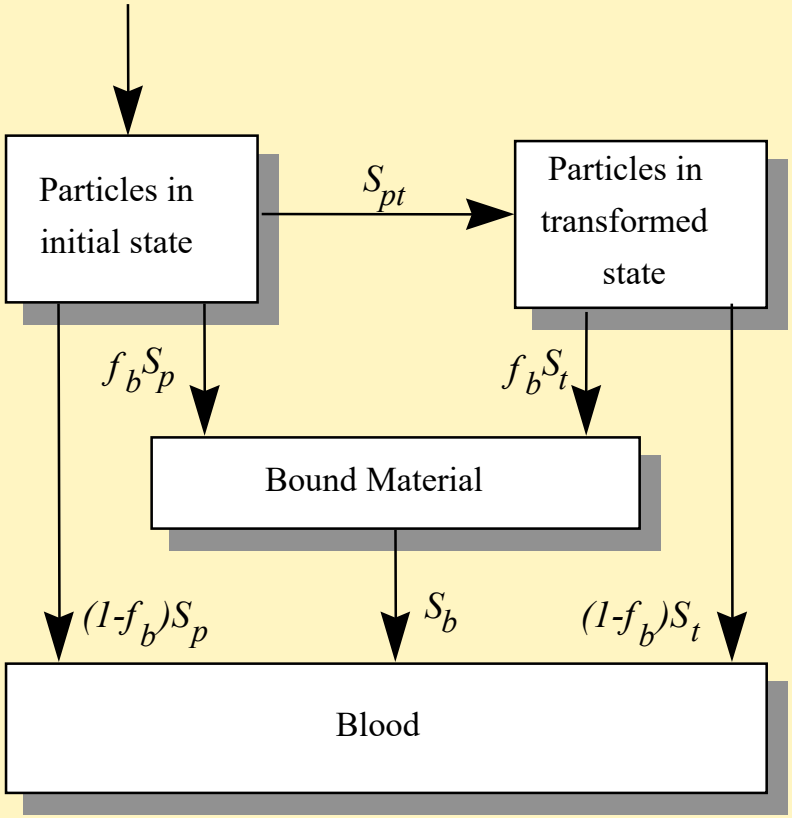


# The ICRP Publication 66 Respiratory Tract Model (1994)




**Deposition of particles:**
**Default: AMAD = 5 μm**

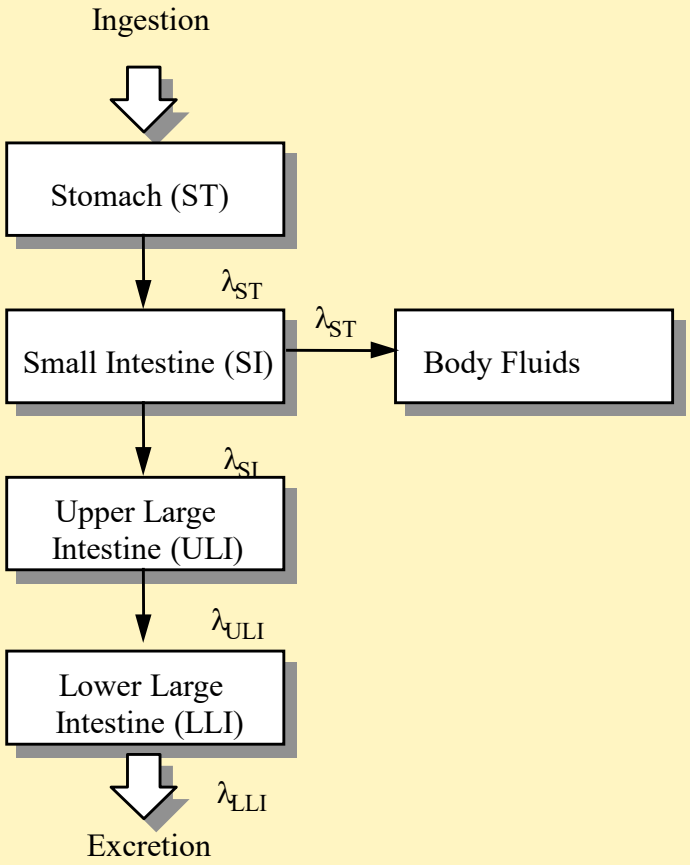
# The ICRP Publication 66 Respiratory Tract Model - Blood Absorption -

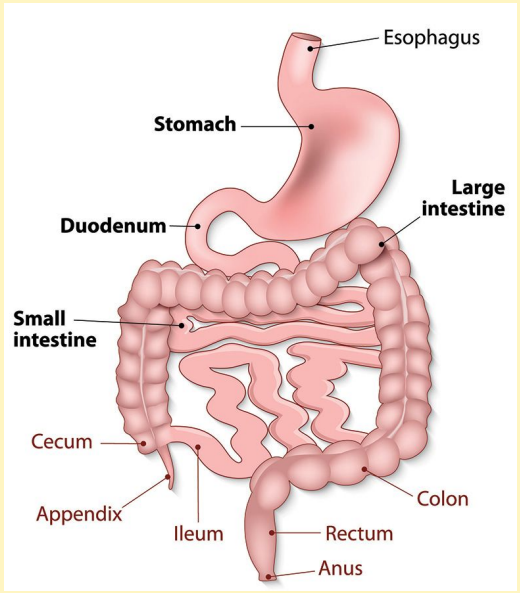



| Absorption Rates ($d^{-1}$) | | | |
|---|---|---|---|
| | F (Fast) | M (Moderate) | S (Slow) |
| Sp | 100.0 | 10.0 | 0.1 |
| Spt | 0 | 90.0 | 100.0 |
| St | --- | 0.005 | 0.0001 |
| Fb | 0 | 0 | 0 |
| Sb | --- | --- | --- |

# *Evolution of the Gastrointestinal Tract Models*

# The ICRP Publication 30 Gastrointestinal Tract Model (1979)



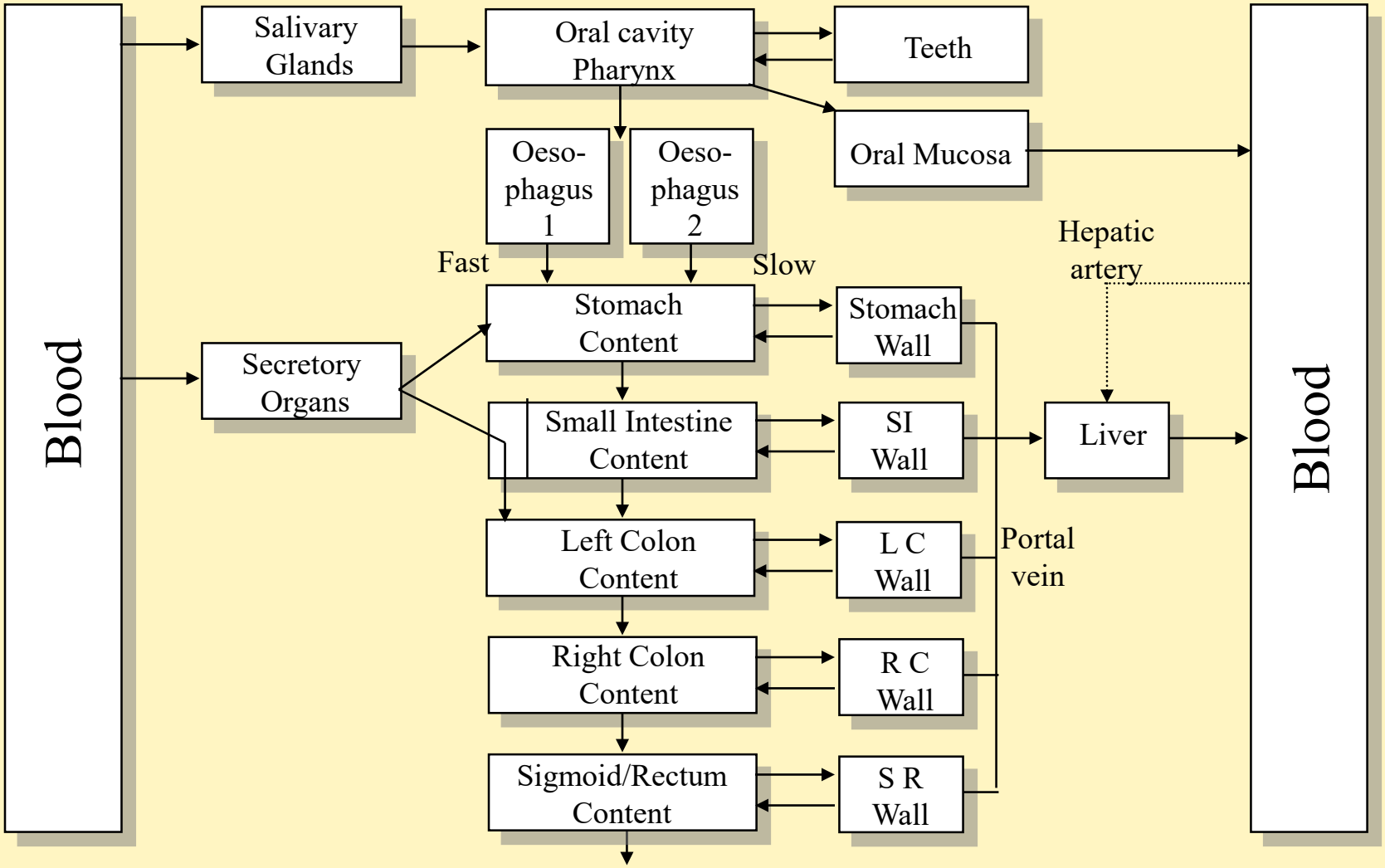

| Section of GI tract | Mass of Contents (g) | Mean residence time (d) | $\lambda$ ($d^{-1}$) |
|---|---|---|---|
| ST | 250 | 1/24 | 24 |
| SI | 400 | 4/24 | 6 |
| ULI | 220 | 13/24 | 1.8 |
| LLI | 135 | 24/24 | 1 |

# *The Need for a New GI Tract Model*

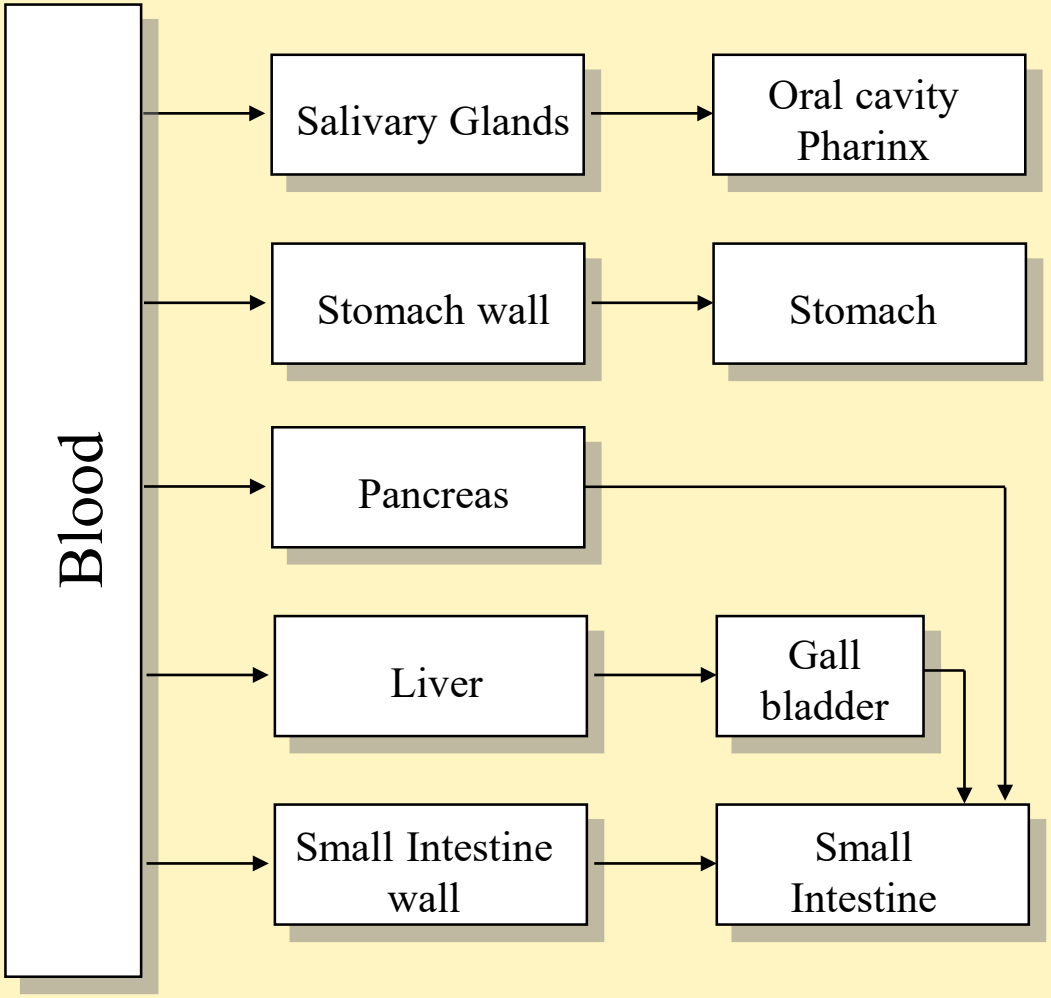
**Since ICRP-30 (1979):**

- **Specific risk estimates for cancer of the esophagus, stomach and colon have been included.**
- **More data available on the transit of materials through the different regions of the gut.**

# Human Alimentary Tract Model for Radiological Protection (2006)

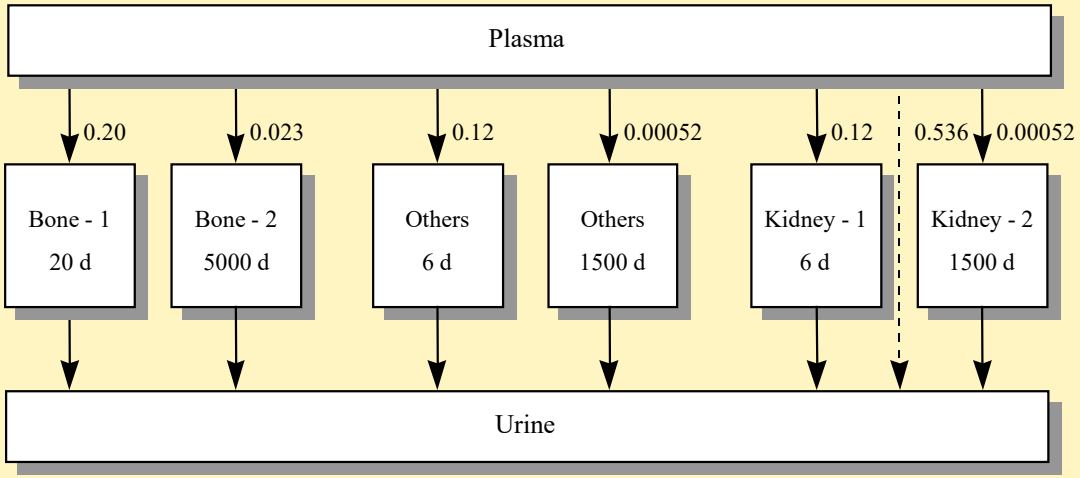


# Routes of Secretion Into the Alimentary Tract

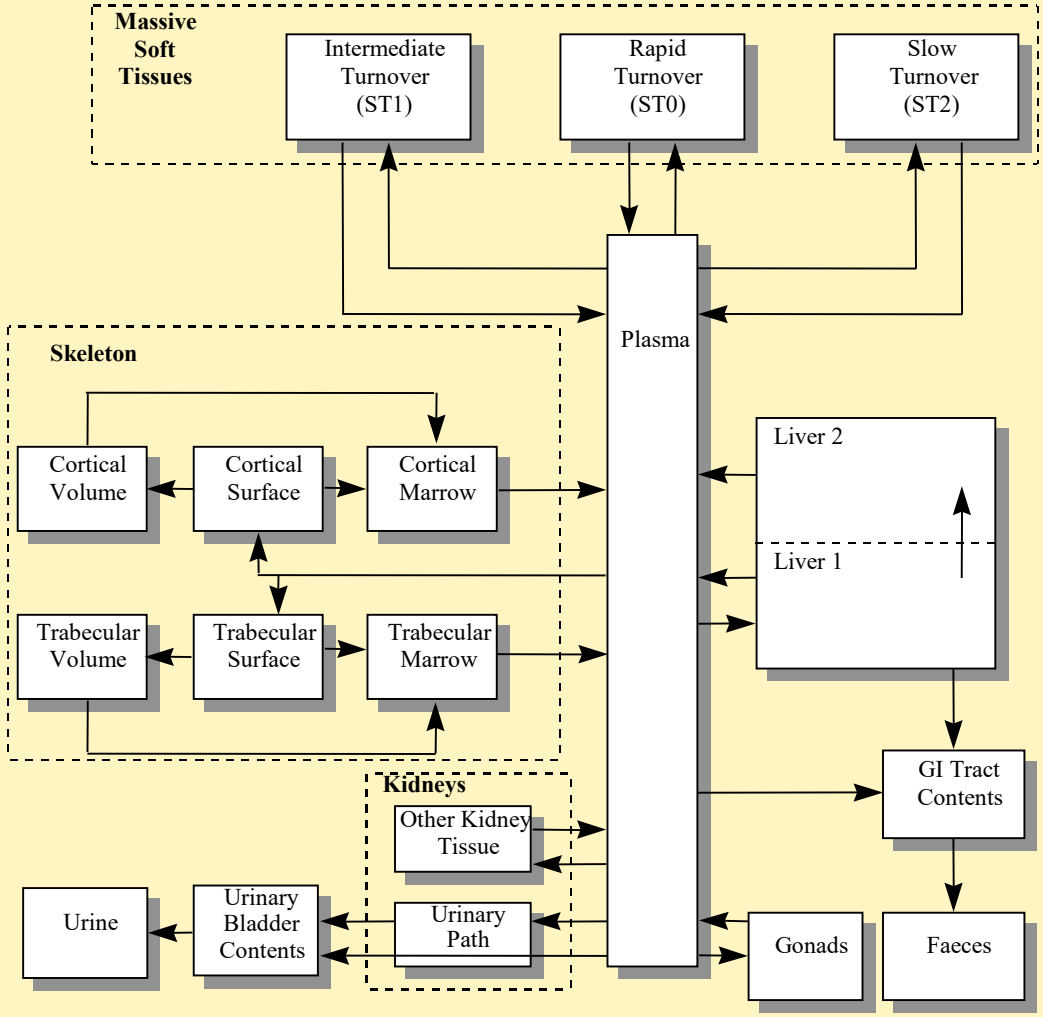


# *Evolution of the Systemic Models*

# The ICRP Publication 30 Uranium Systemic Model (1979)

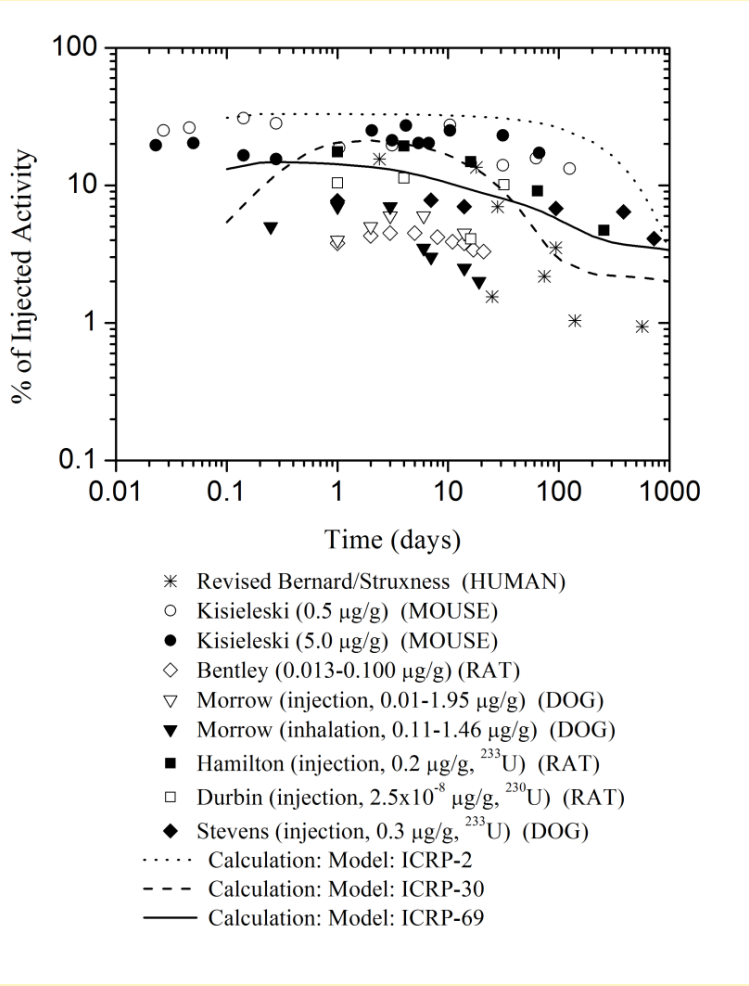


# The ICRP Publication 69 Systemic Model for Actinides and Thorium (1994)

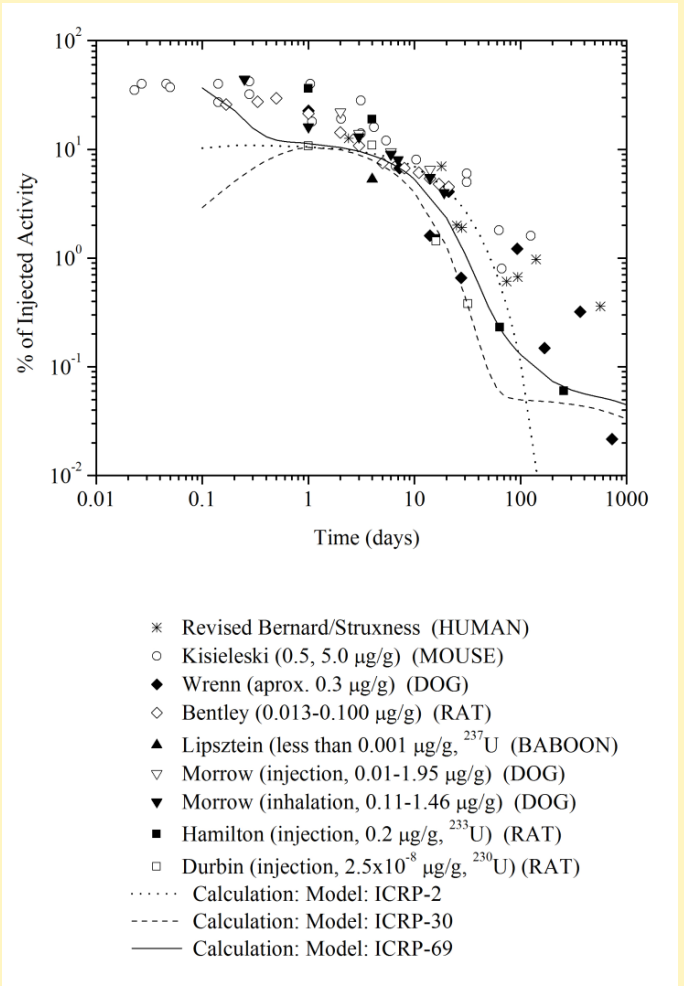


# Organ Content (%) After a Single Injection of Soluble Uranium

## Skeleton




## Kidneys



# *Evolution of the Dosimetric Models*

# The ORNL Adult Male Phantom (1974)

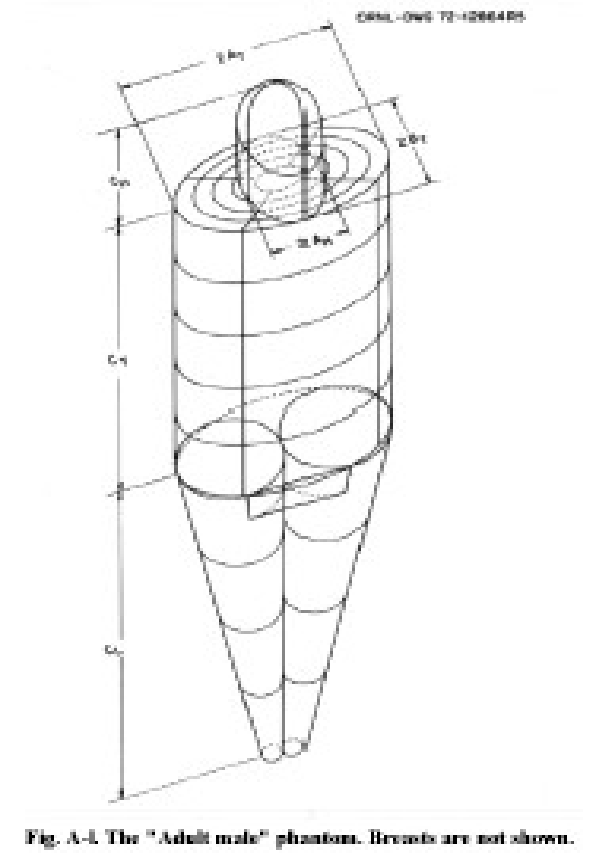


Fig. A-4. The "Adult male" phantom. Breasts are not shown.

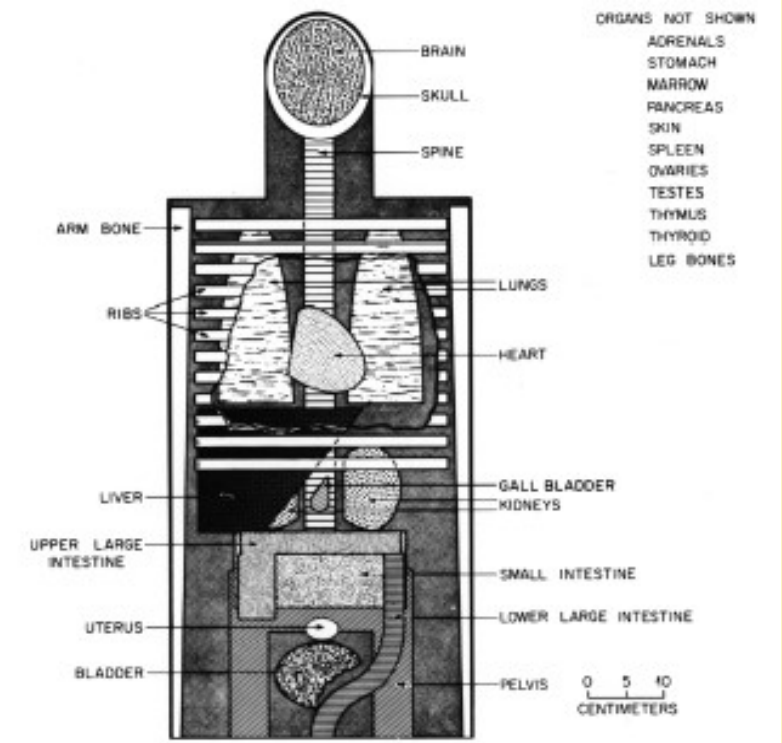



**Fig. A-3. Anterior view of the principal organs in the head and trunk of the adult phantom developed by Snyder et al. (1974).** Although the heart and head have been modified in this report, this schematic illustrates the simplicity of the geometries of the organs.

# Phantom Evolution

***Stylized Phantoms***

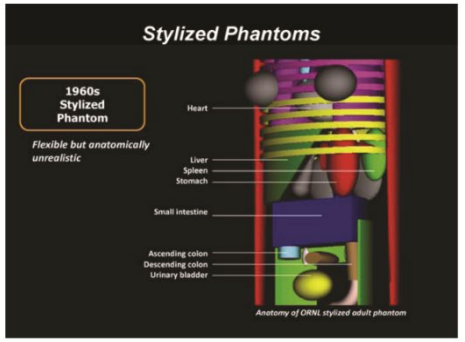
**Organ / body contours defined by 3D mathematical surface equations**

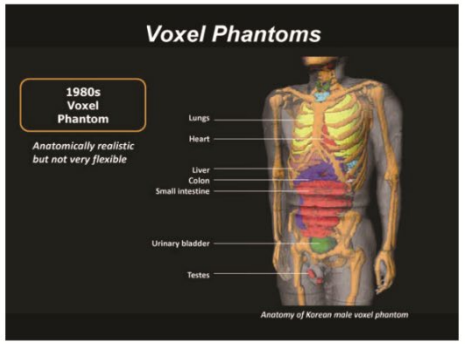
***Voxel Phantoms***

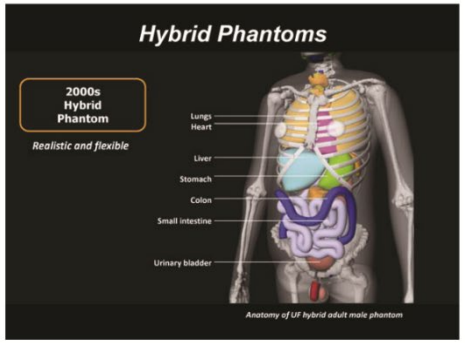
**Organs and body tissues defined by groupings of 3D arrays of tagged image volume elements**

***Hybrid Phantoms***

**Organ / body contours defined by NURBS or polygon mesh surfaces**



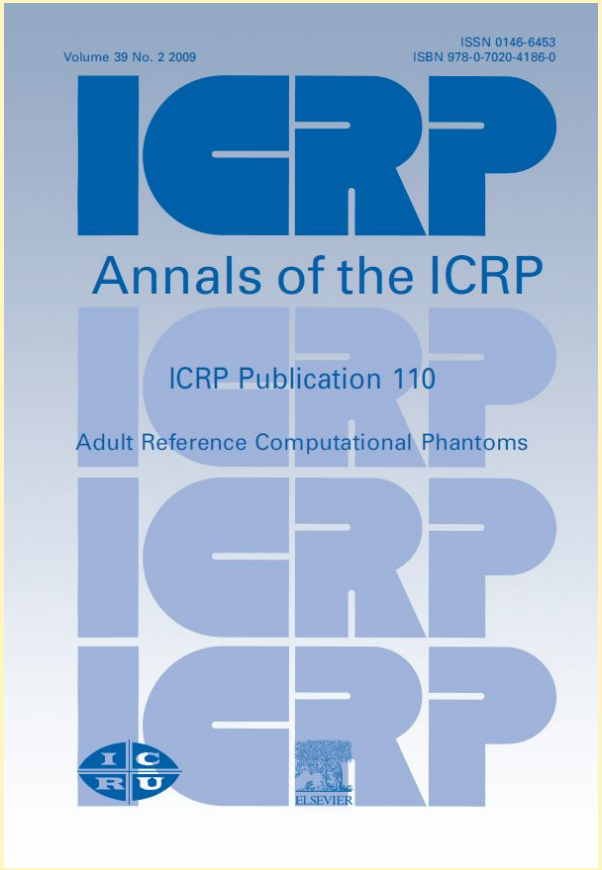



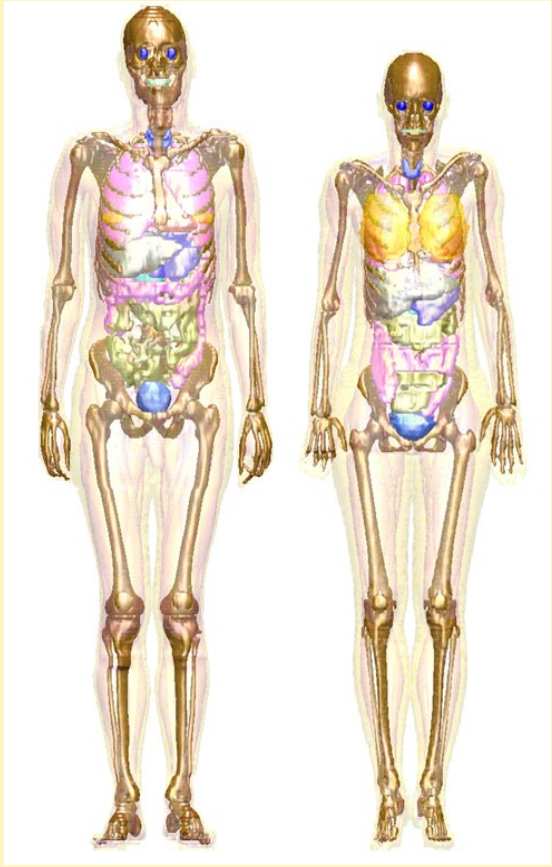




Non-uniform rational basis spline (NURBS) is a mathematical model commonly used in computer graphics for generating and representing curves and surfaces.

# *ICRP Adult Reference Computational Phantoms – Voxel Based*

**ICRP Publication 110 (2009)**

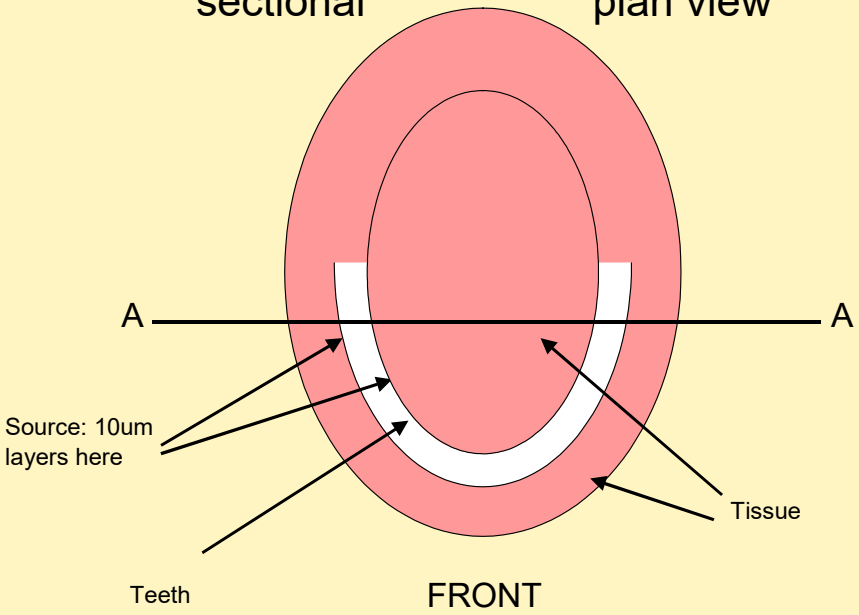


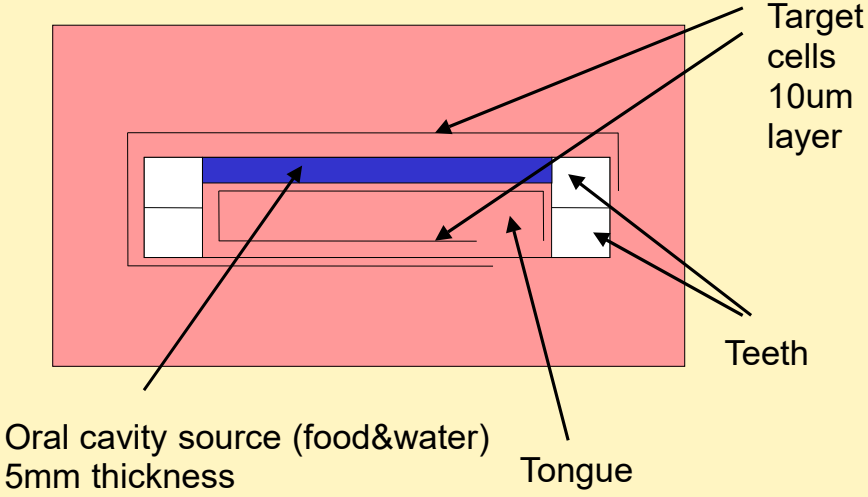
# Dosimetric Model for Oral Cavity

Schematic of Oral Cavity dosimetric model

sectional plan view



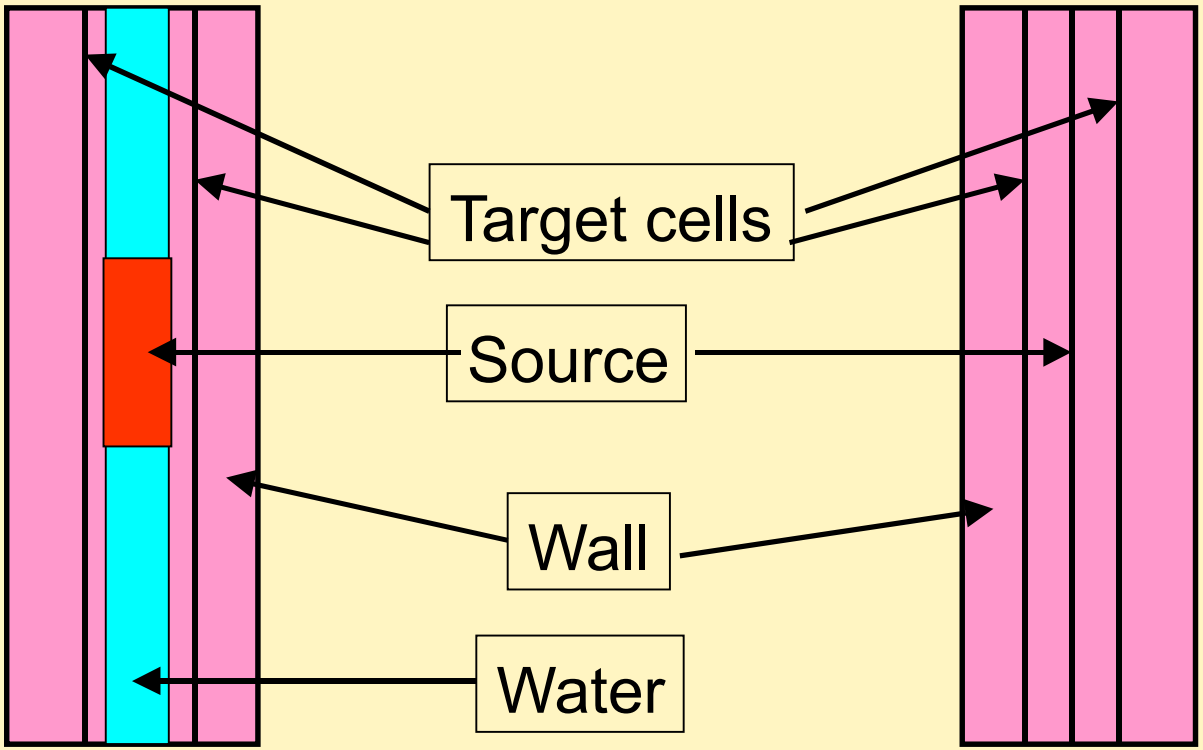

**Schematic of Oral Cavity model**
**Sectional front view**



# *Dose to Target Cells in the Esophagus*

**Esophagus fast and other sections**

**Esophagus slow**



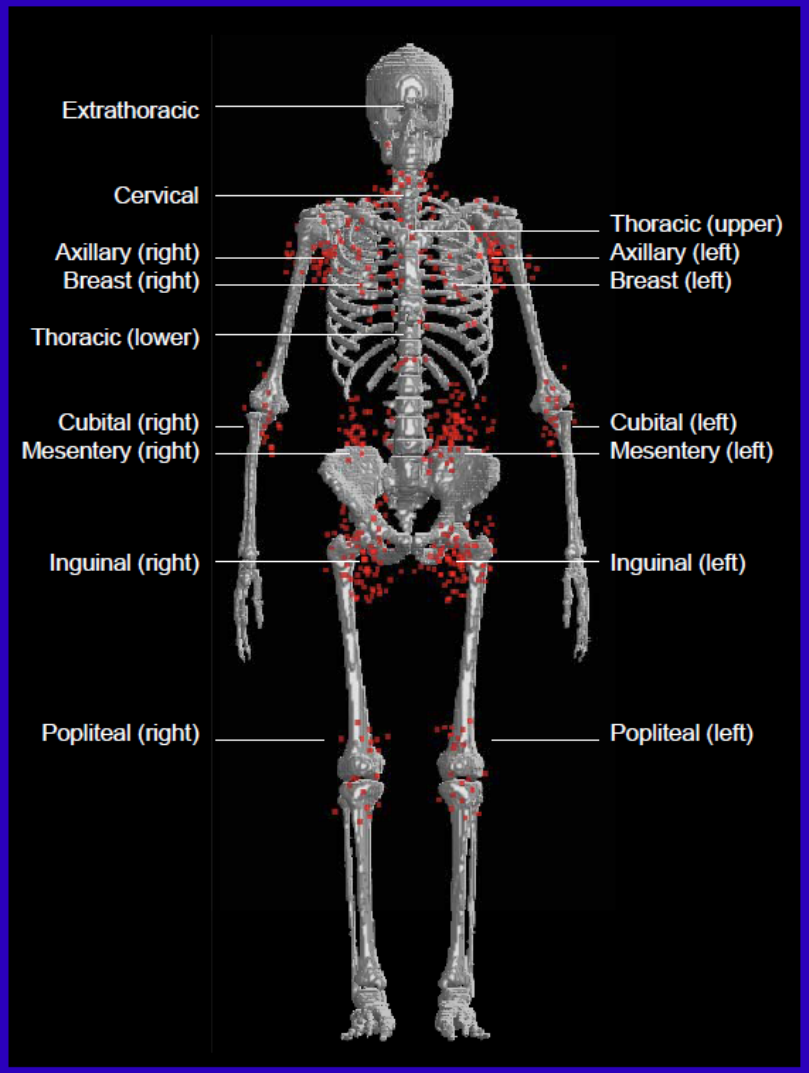
# *Remarks on the Evolution of Internal Dosimetry*

- **Effects of radiations have been reviewed by the ICRP Main Commission → Last: ICRP-103 (2007).**
- **Biokinetic and dosimetric models are becoming more and more realistic and are constantly being reviewed by the ICRP Committee 2 and its task groups.**
- **Specific biokinetic and dosimetric models for internal dose calculations have also been developed for members of the public of all groups of age, including embryo, fetus and nursing infants.**

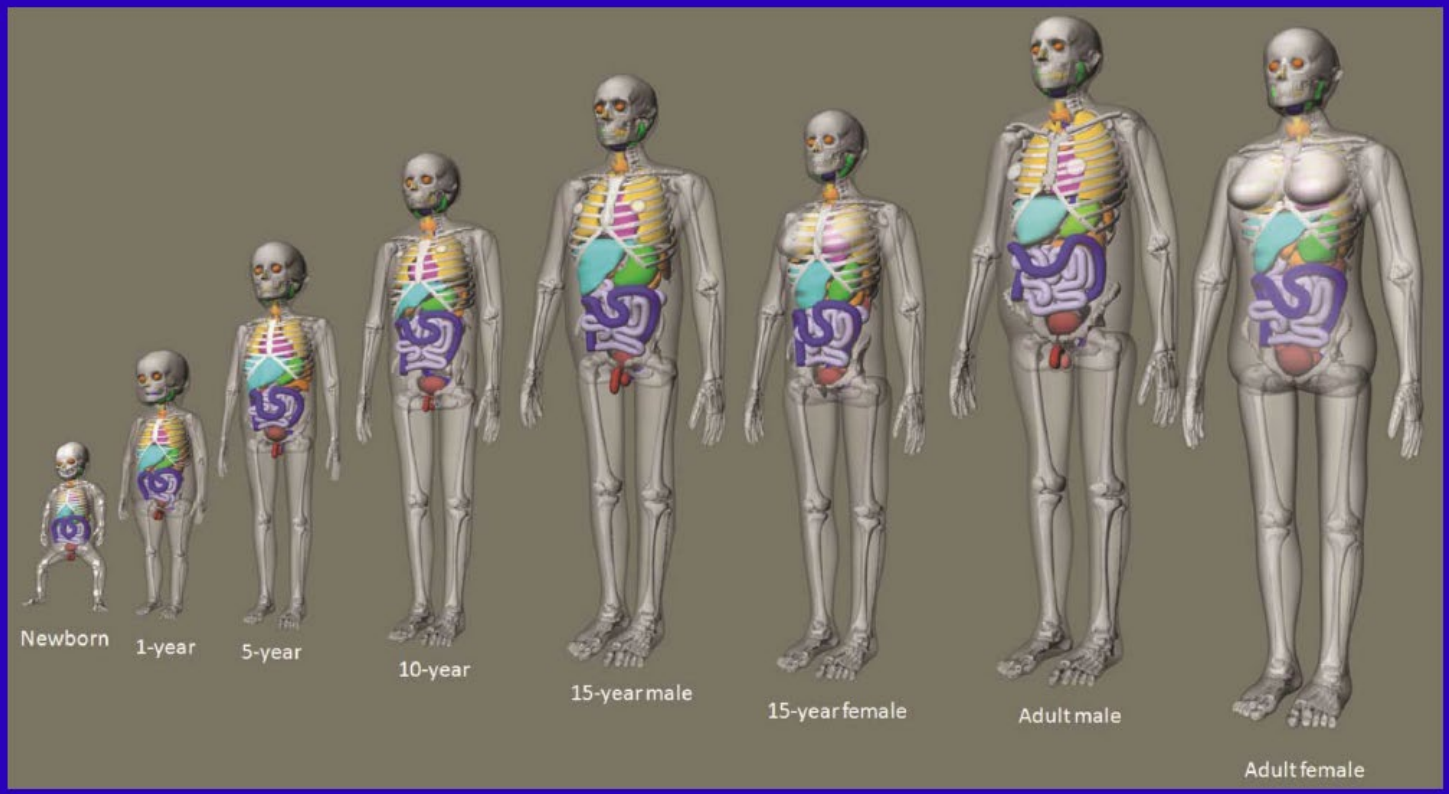
# Lymphatic Nodes

## *Lymphatic node model*

- *16 different sites*
- *Match ICRP89 mass (1%)*
- *Semi-automated MATLAB code*
- *Need to verify pediatric values*



# Pediatric Hybrid Phantoms



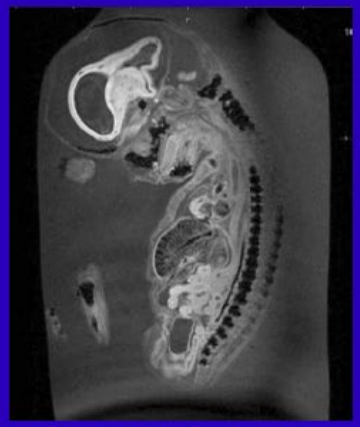

**The UF family of reference hybrid phantoms for computational radiation dosimetry**

Choonsik Lee[1], Daniel Lodwick[2], Jorge Hurtado[2], Deanna Pafundi[2], Jonathan L Williams[3] and Wesley E Bolch[4,5]

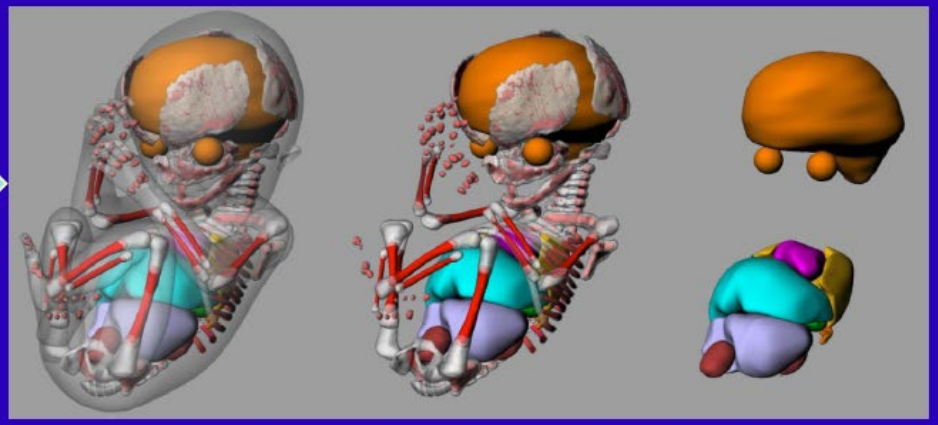
IOP PUBLISHING

Phys. Med. Biol. 55 (2010) 339–363

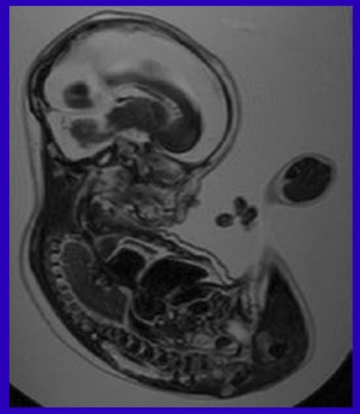
# Fetal Model Development



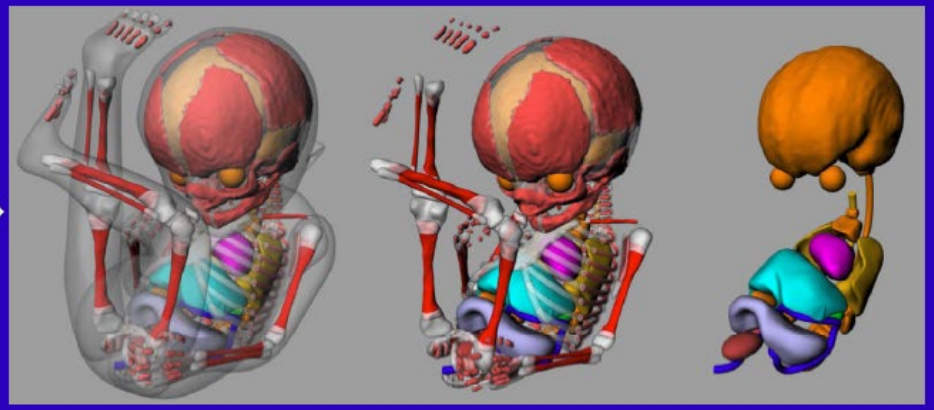
*4.7 T NMR Image*
*11.5 week fetus*



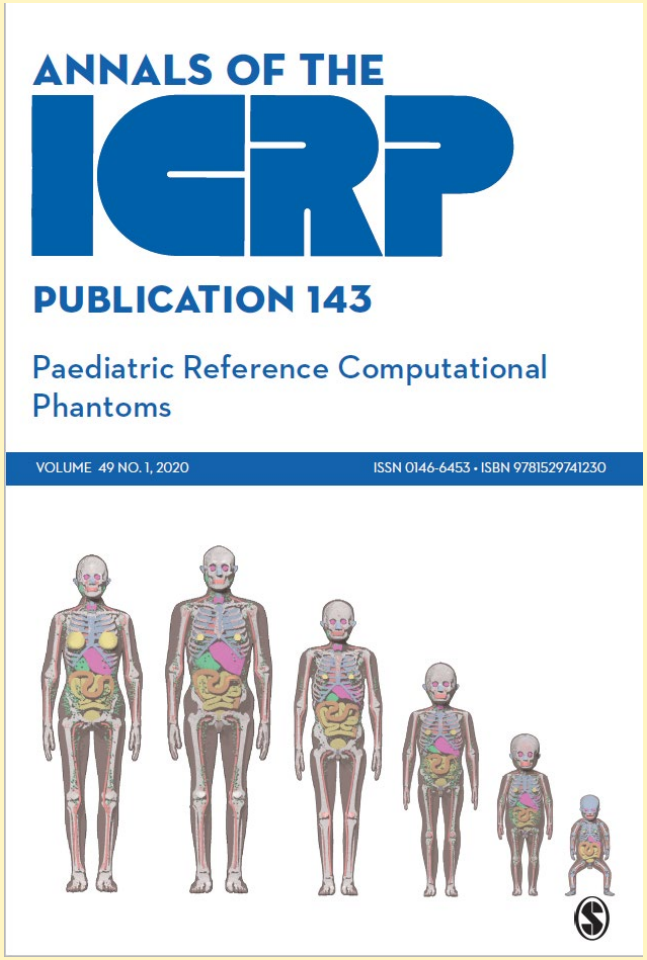
*Two Specimen-Specific Fetal Models*

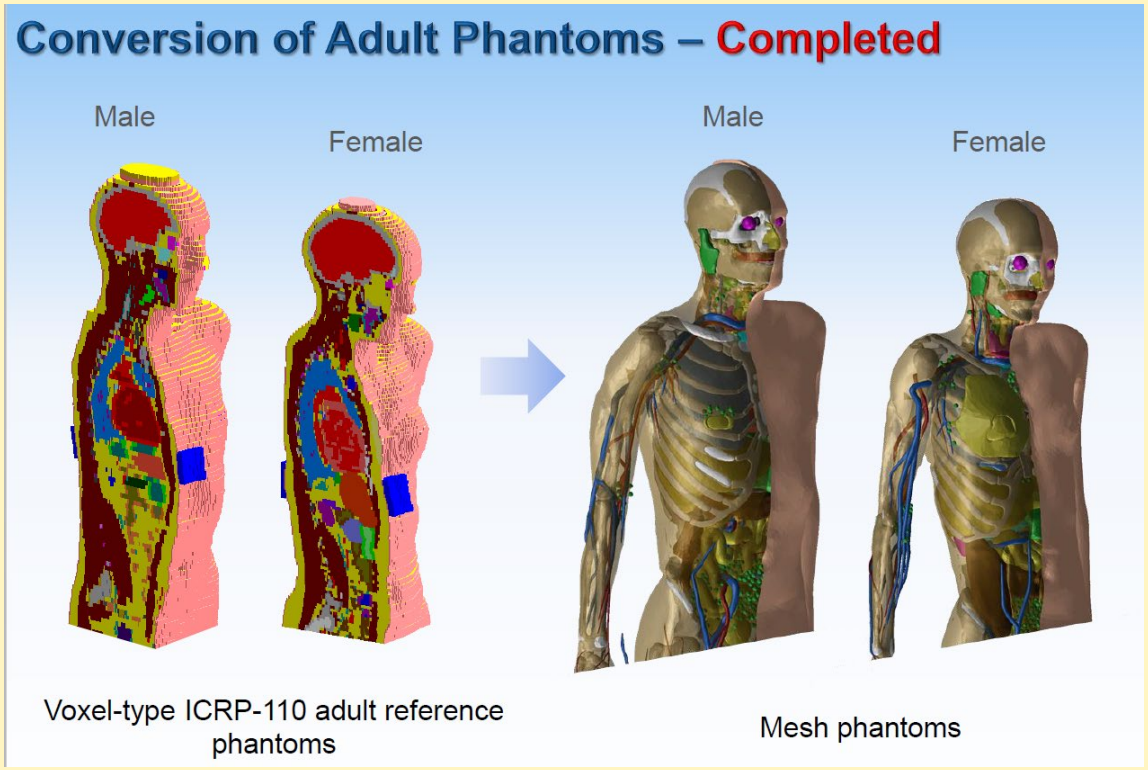


*1.5 T MR Image*
*21 week fetus*



# New Reference Phantoms



# *Best of Luck!*

My sincere
best wishes
to you all !!!

**Thanks!**